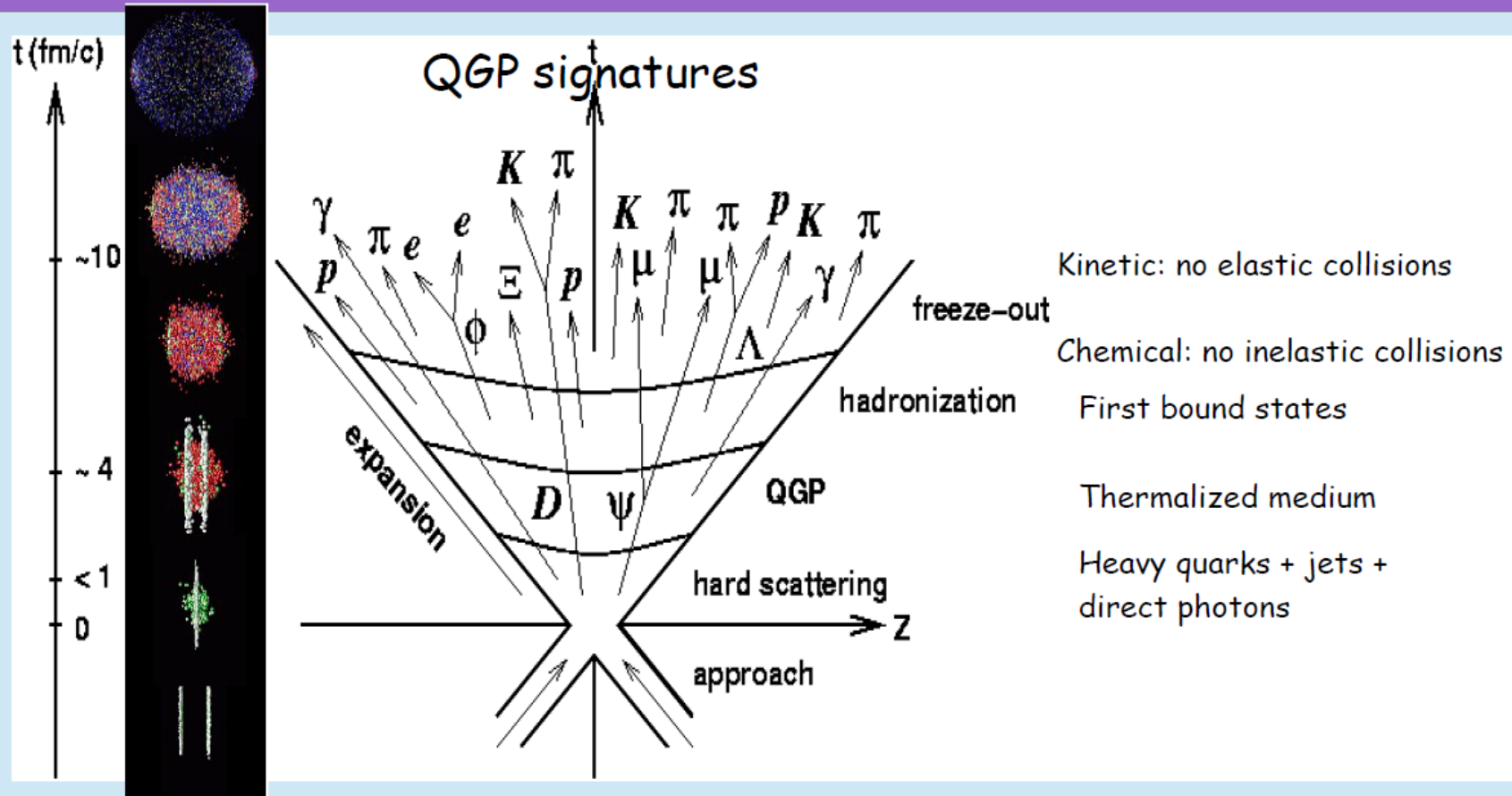


Strange baryons with ECAL at BM@N

A.Golubev, S.Kiselev, D.Kirin, I.Larin,
V.Semyachkin, S.Shimanskiy,
A.Stavinskiy, V.Tarassov, N.Zhigareva

Motivation: the QGP

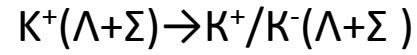
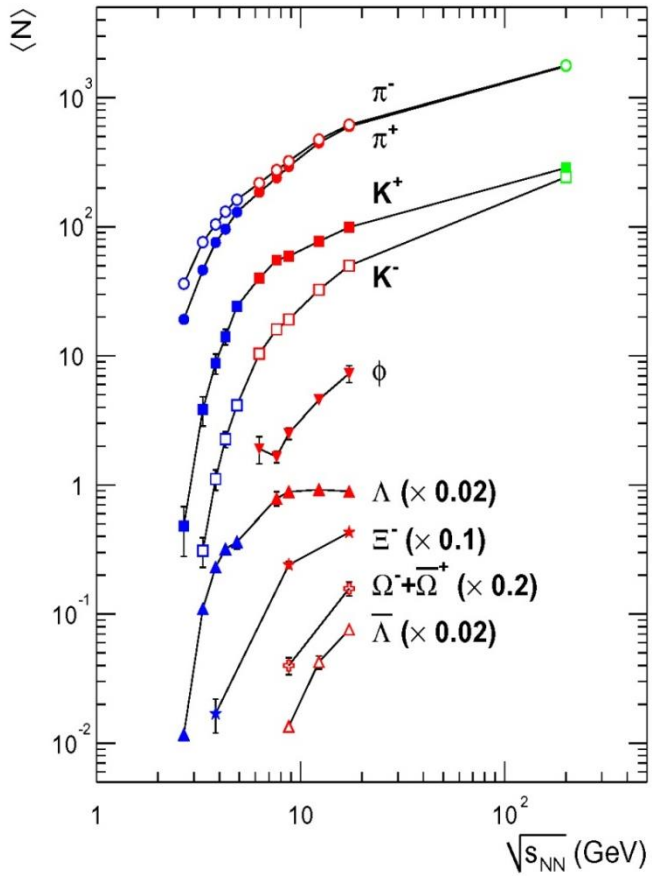


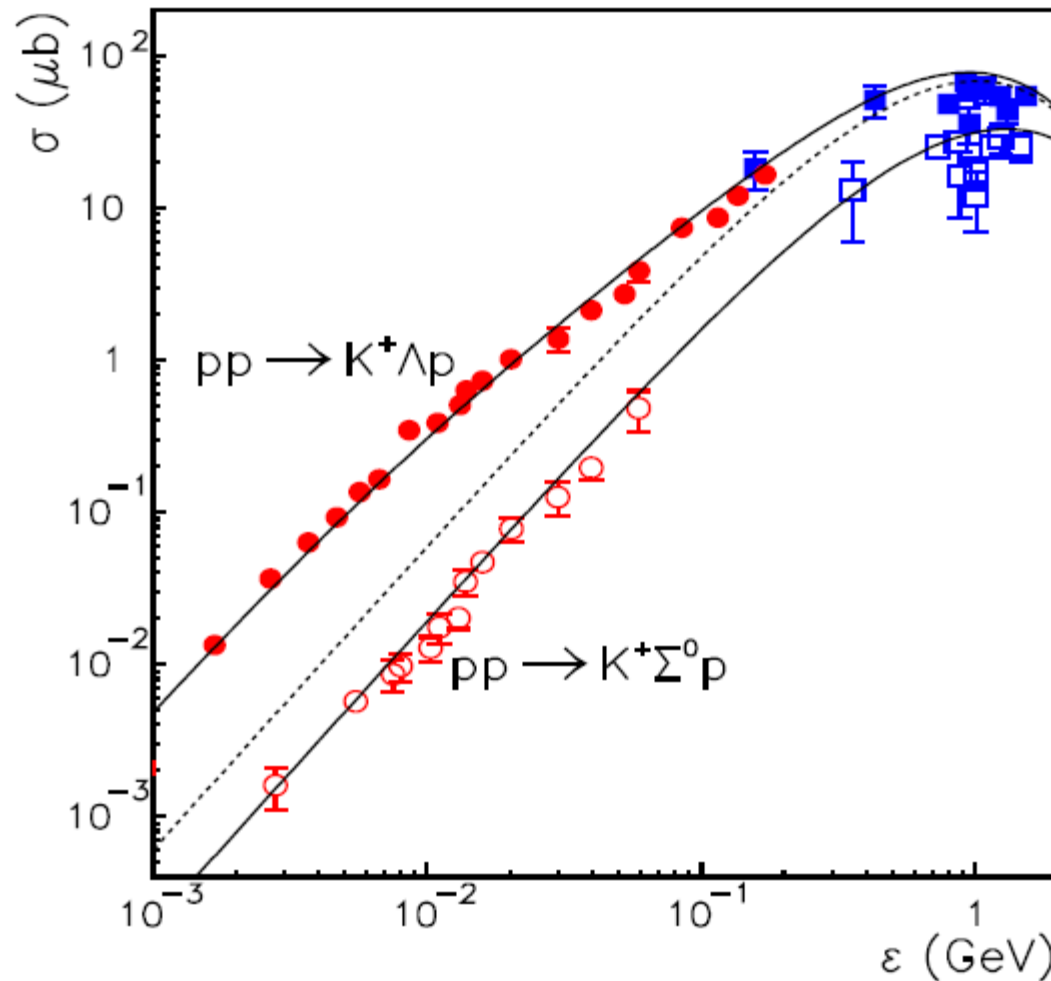
Strange baryons: Λ, Ξ^- . Why no $\Sigma(\Sigma^-, \Sigma^0, \Sigma^+)$?

CC,UrQMD,10 ⁵ ev.	2AGeV	3AGeV	4AGeV	10AGeV	30AGeV
All particles	2968383	3269875	3555732	4785049	6861519
P	980372	973357	964317	934470	899765
N	982267	974936	965797	937139	900696
Λ	1393	5493	10405	30537	57559
Σ^+	489	2347	4389	11135	17909
Σ^0	623	2918	5653	12424	19557
Σ^-	549	2277	4321	11209	18108
π^+	178772	269480	354107	714208	1286150
π^0	205822	312142	407661	796030	1418912
π^-	178205	267809	354088	713459	1286178
K^+	1607	6884	13574	45080	108427
K^0	1506	6741	13218	44376	108090
anti K^0	30	279	942	11760	51677
K^-	27	279	918	11516	51639

3AGeV: $K^+ + K^0$ (13625) \sim $\Lambda + \Sigma$ (13035).

AGS NA49 BRAHMS





arXiv:hep-ph/0608098,
A.Sibirtsev et al.

No FSI for Σ ?

Fig. 1. Total cross sections for the $pp \rightarrow K^+ \Lambda p$ (closed symbols) and $pp \rightarrow K^+ \Sigma^0 p$ (open symbols) reactions as a function of the excess energy ϵ . Results from COSY [1,2,11,13,14] are indicated by circles, while the squares are data from Ref. [25]. The solid lines are our results for the Λ and Σ^0 reaction channels, respectively. The dashed line is obtained by switching off the Λp final-state interaction.

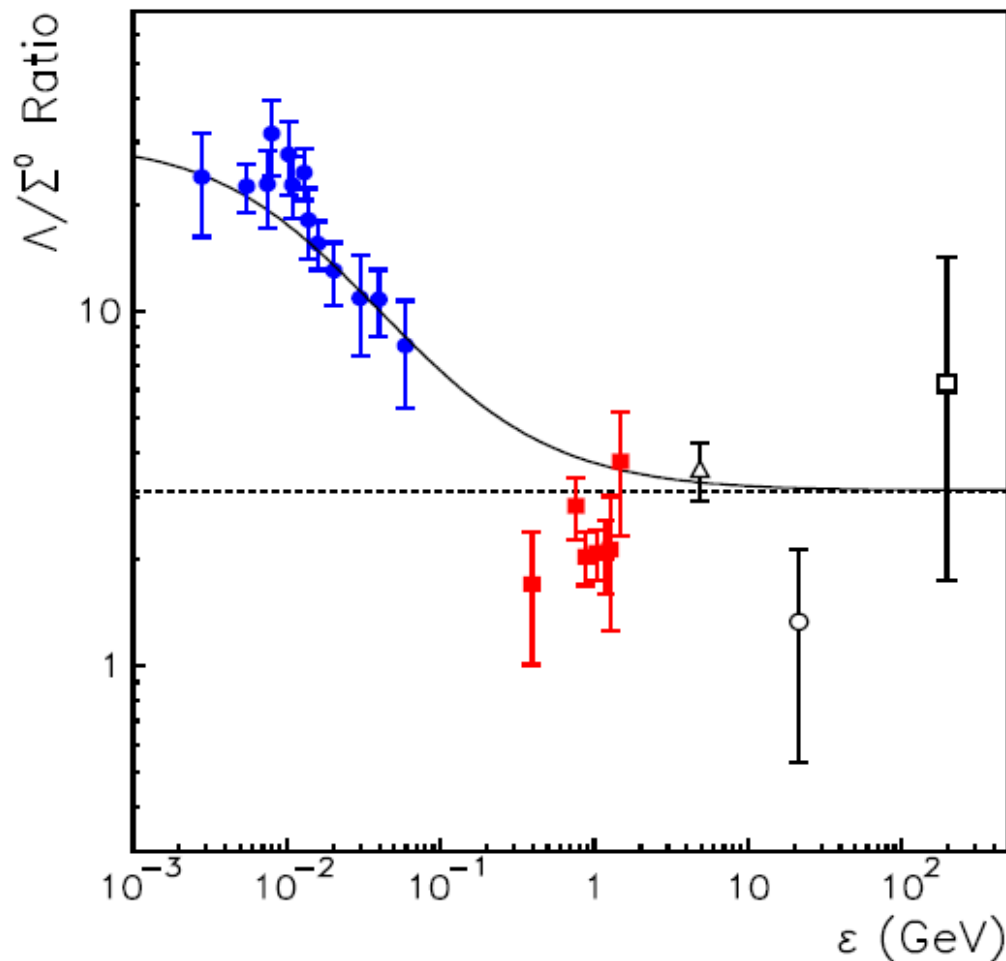


Fig. 3. The Λ/Σ^0 cross section ratio as a function of the excess energy ϵ . The solid circles show the ratio obtained for the $pp \rightarrow K^+ \Lambda p$ and $pp \rightarrow K^+ \Sigma^0 p$ reactions at COSY [2]. Solid squares are pp results from Ref. [25]. The open triangle and open circle are ratios measured in $p\text{Be}$ [28] and $p\text{Ne}$ [29] collisions, respectively. The open square is the result from a $d\text{Au}$ experiment [30]. The curves are cross section ratios based on the $pp \rightarrow K^+ \Lambda p$ results with Λp FSI (solid line) and without FSI (dashed line).

“It is interesting to observe that the ratios for nuclear targets, measured at high energies, are roughly in line with the results from high-energy pp collisions. Unfortunately, the new and still preliminary STAR result is afflicted by large uncertainties and, thus, precludes any firm conclusion concerning a possibly larger ratio with respect to that found in the pp interactions. Several authors have pointed out that the experimental ratio of around 3 coincides with the ratio of the isospin multiplicity of the Λ and Σ 's [2,28,30]. But we are not aware of any deeper reason why those two quantities should be connected.”

arXiv:hep-ph/0608098,
A.Sibirtsev et al.

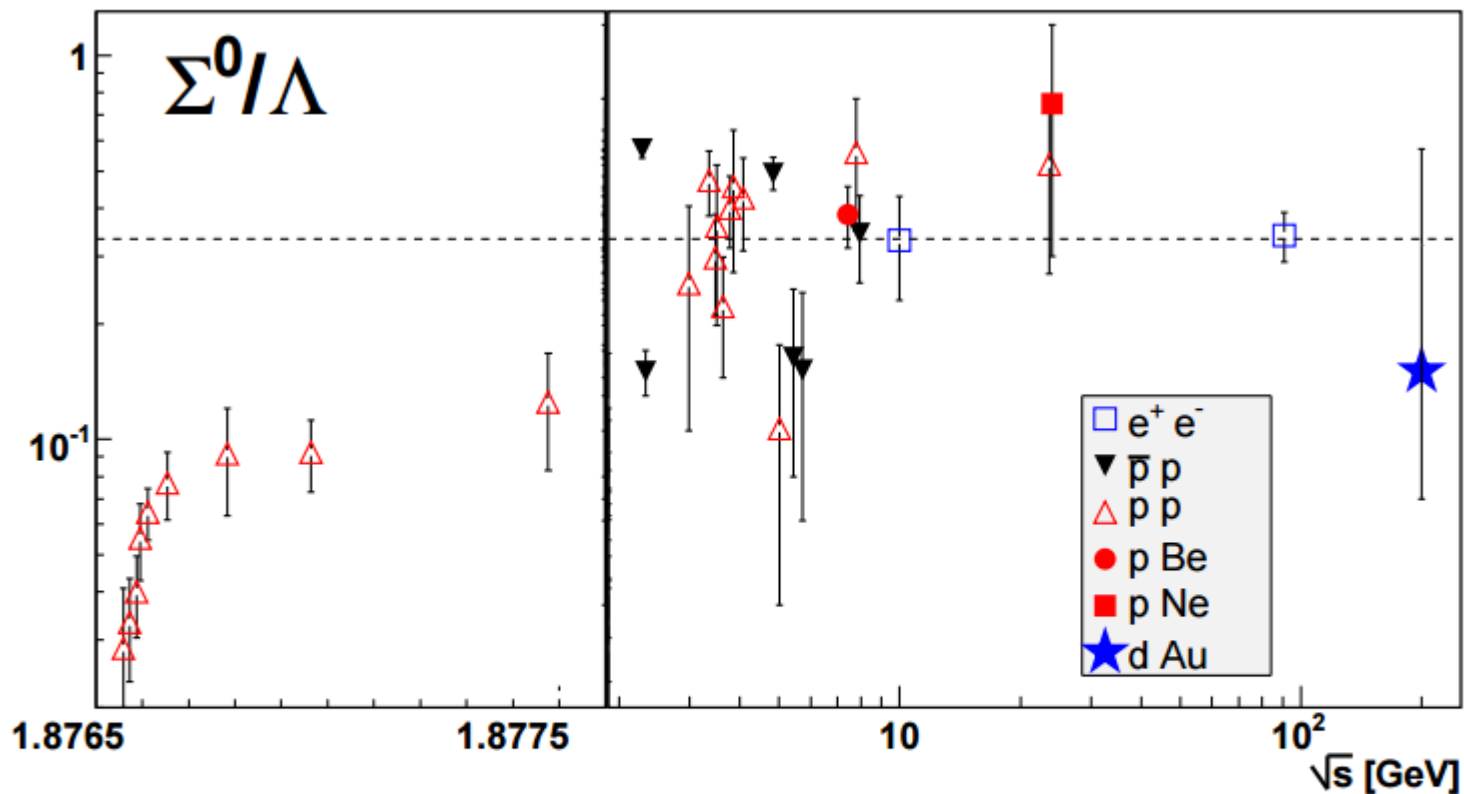


Figure 4: Σ^0/Λ results versus collision \sqrt{s} ($\sqrt{s_{NN}}$ for p/d+A) [1]. Meson-nucleon reaction results are excluded for clarity, but exist only at intermediate energies and lie in the same range. The dashed line is the ratio of isospin degeneracy factors (1/3).

arXiv:nucl-ex/0512018, G. Van Buren for the STAR collaboration

FSI depends on the size of the interaction region ($\sim 1/r^2$), Λ/Σ ($E \rightarrow 0$) 3 for AA in contrast to Λ/Σ ($E \rightarrow 0$) 30 for pp? No data!

$E \gg 1 \text{ GeV}$ (no FSI)

Model baryon = quark + diquark:

“ diquark: $T=S=1$ or 0 .”

И.Ю.Кобзарев, Б.В.Мартемьянов, М.Г.Щепкин

УФН 162, вып.4, 1992, стр.1-41

See, also, Anisovich A.V., et al., Int. J. Modern Phys. A, 25:15 (2010);

arXiv:1001.1259[hep-ph]

(Quark-Diquark Systematics of Baryons)

Femtoscopy.

Λ : $\Sigma(1385) \rightarrow \Lambda\pi(87\%), \Sigma\pi(12\%), \Sigma^0 \rightarrow \Lambda\gamma(100\%), \Xi^0 \rightarrow \Lambda\pi^0(99.5\%),$
 $\Xi^- \rightarrow \Lambda\pi^-(99.9\%)$

P: $\Lambda \rightarrow p\pi^-(64\%), \Sigma^+ \rightarrow p\pi^0(52\%), \Sigma^0 \rightarrow \Lambda\gamma(100\%) \rightarrow p\pi^-(64\%)$

To measure Λp , better to know $\Xi^0 p, \Xi^- p, \Sigma(1385)p, \Sigma^0 p, \Sigma^+ \Lambda, \Lambda\Lambda, \Sigma^0 \Lambda$ interactions.

$$a_{pp}(^1S_0)=-7.8 \text{ fm}; a_{np}(^1S_0)=-23.7 \text{ fm}; a_{nn}(^1S_0)=-16.4 \text{ fm}.$$

$$a_{p\Lambda}(^1S_0)=-2.7 \text{ fm}; a_{\Sigma+p}(^1S_0)=-3.85 \text{ fm}; a_{\Lambda\Lambda}(^1S_0)=-0.88 \text{ fm}[1]$$

[1] Th.A.Rijken, M.M.Nagels, Y.Yamamoto,
Progress of Theoretical Physics Suppl.NO.185(2010),14

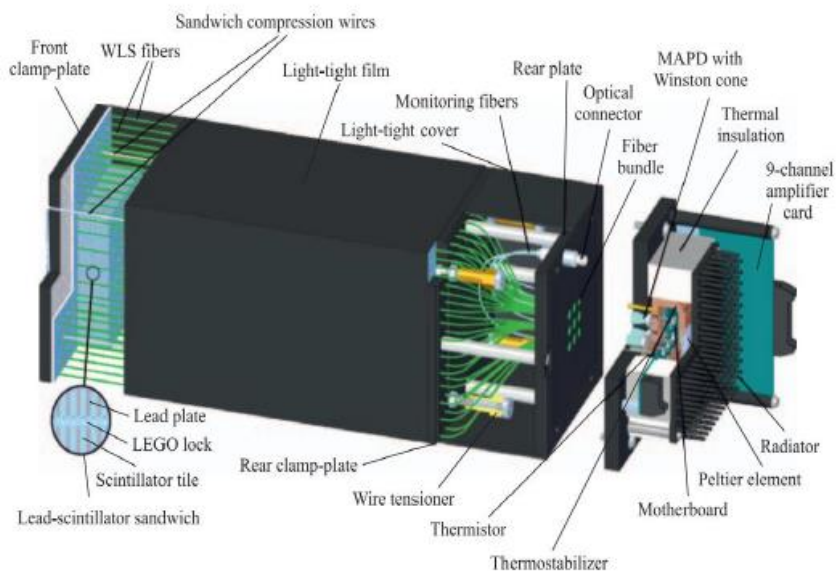
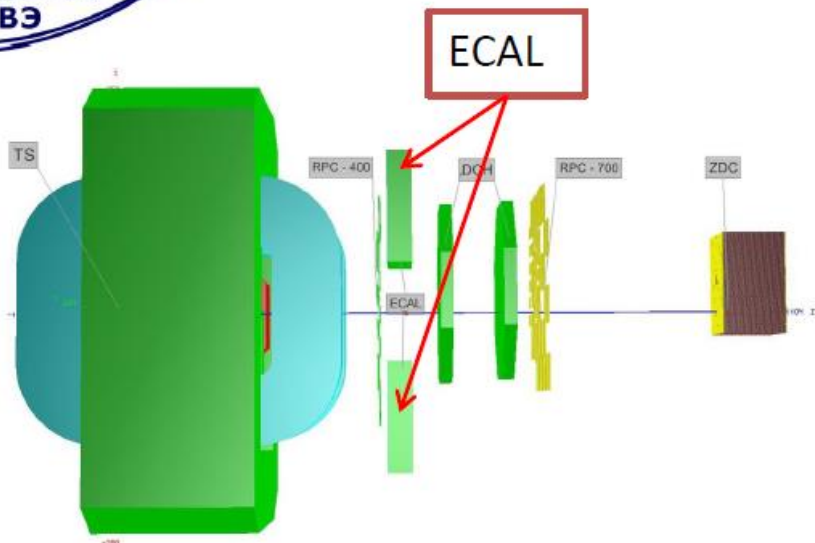
Σ^+ DECAY MODES Fraction (Γ_i/Γ)
 $p\pi^0$ (52 %)
 $n\pi^+$ (48 %)

Σ^0 DECAY MODES Fraction (Γ_i/Γ)
 $\Lambda\gamma$ (100 %)

Σ^- DECAY MODES Fraction (Γ_i/Γ)
 $n\pi^-$ (100 %)

To identify Σ one needs detectors for γ and n .

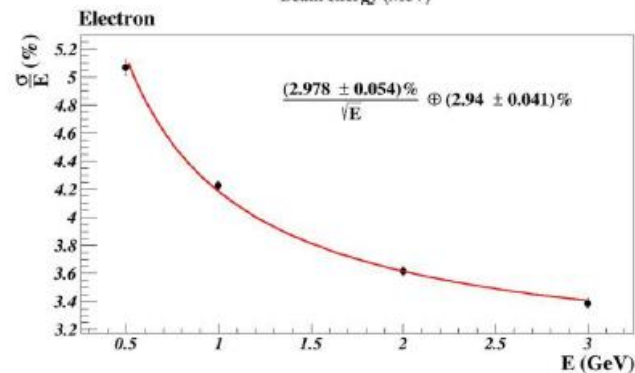
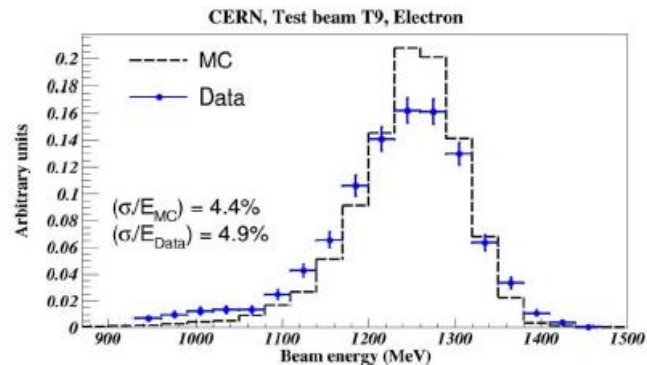
Electromagnetic calorimeter (optional)



Design of the Shashlyk type calorimeter module

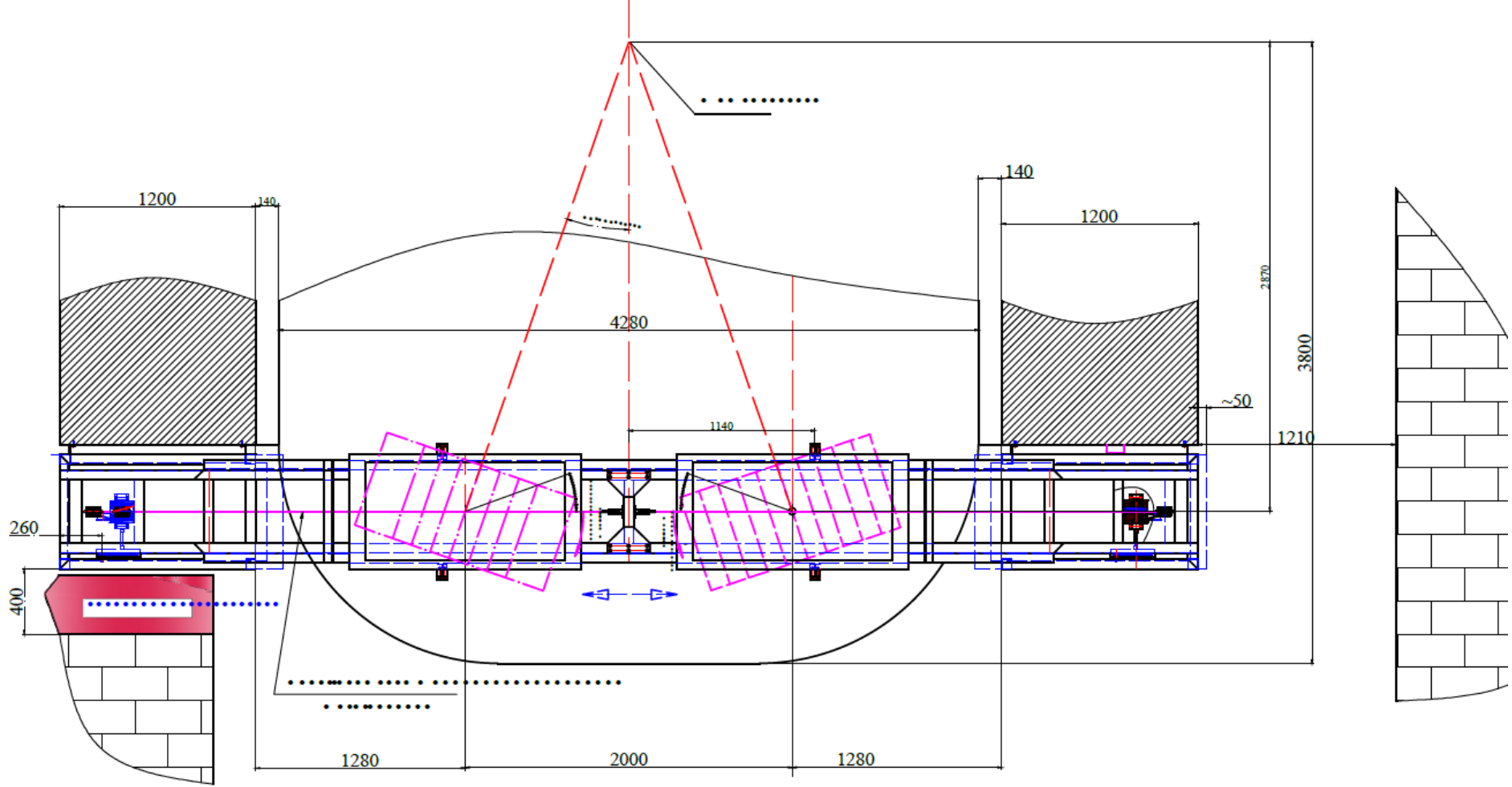
I.Tyapkin

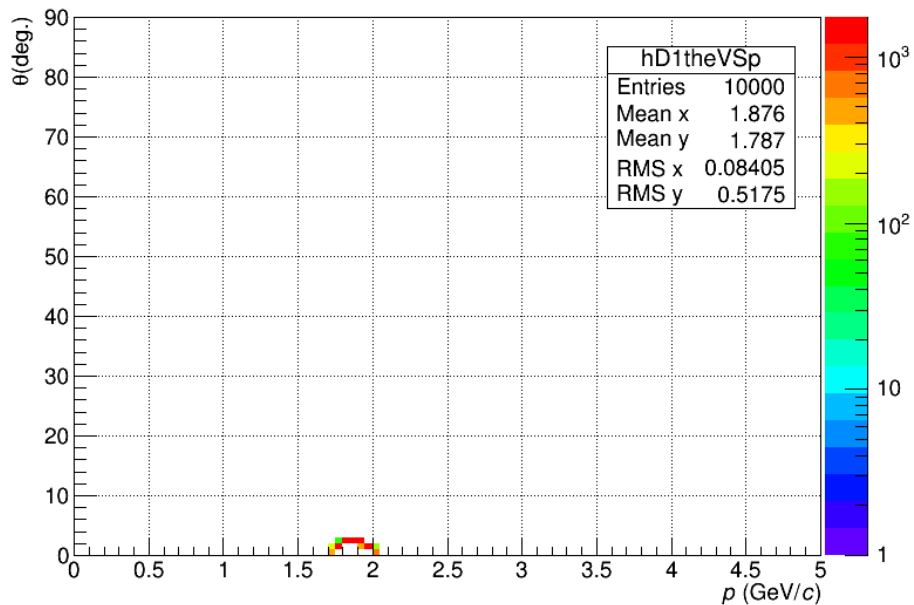
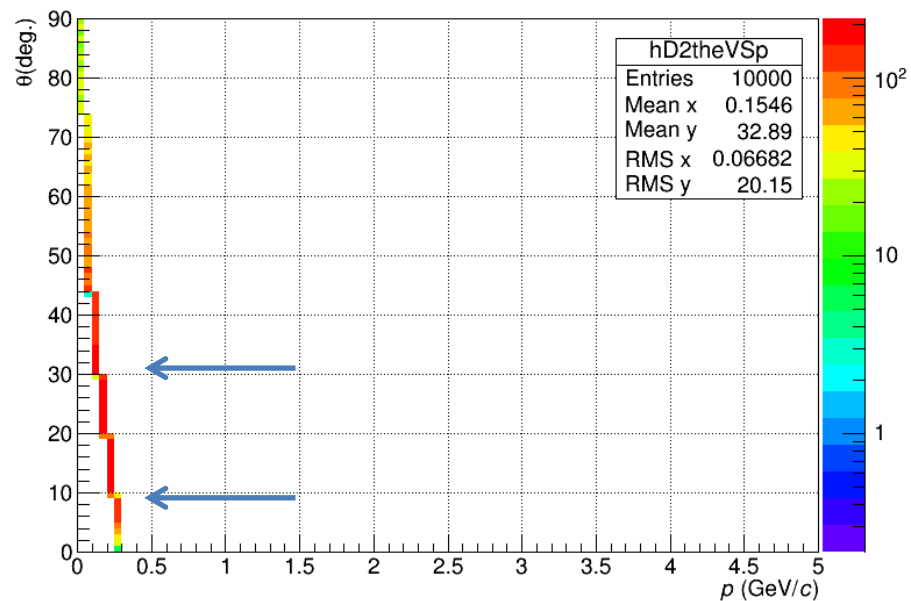
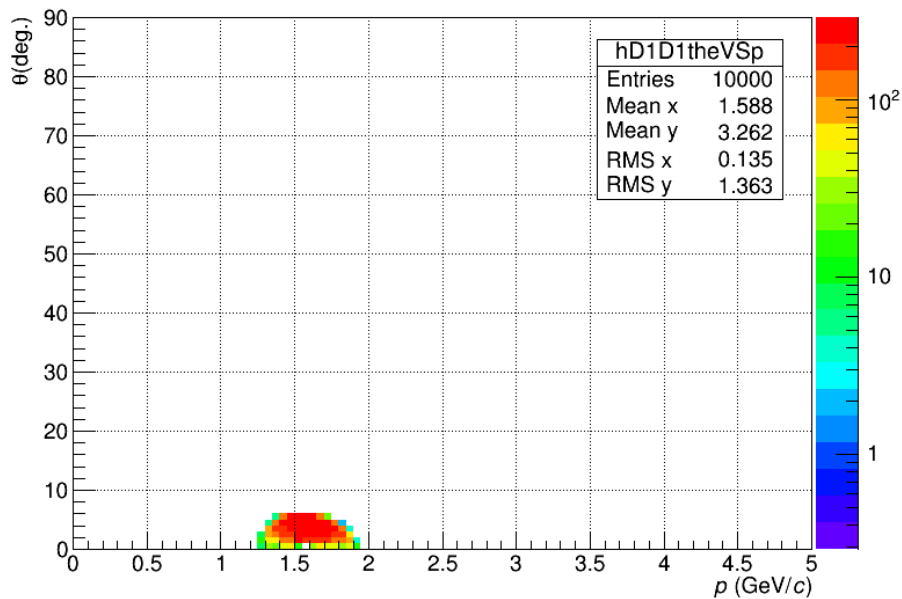
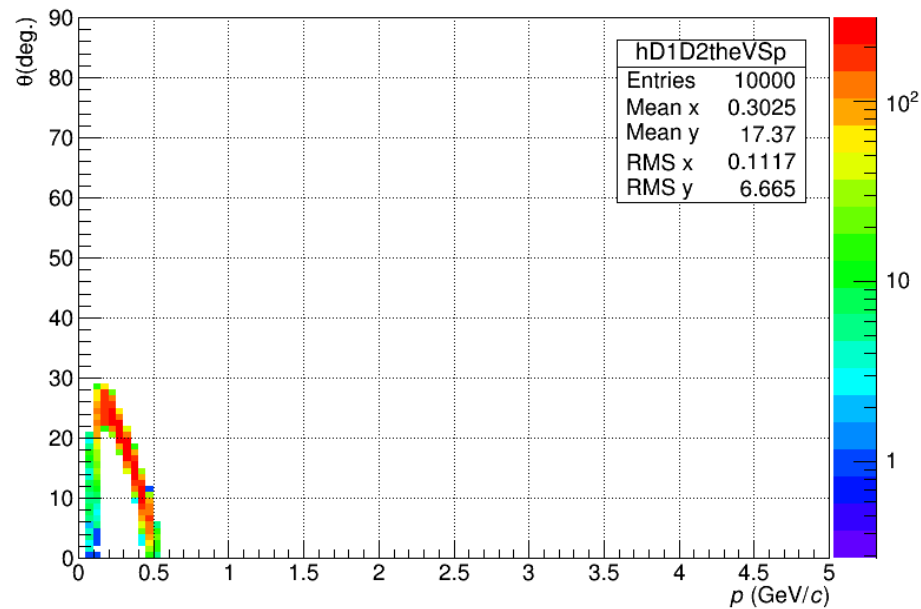
Energy resolution



Parameters

Transverse size, mm ²	40x40
Module size, mm ²	120x120
Number of layers	220
Lead absorber thickness, mm	0.3
Polystyrene scintillator thickness, mm	1.5
Molière radius, mm	26
Radiation length, X ₀	11.8



Λ from Σ^0 ($p=2$ GeV, $\theta=0$ deg.) γ from Σ^0 ($p=2$ GeV, $\theta=0$ deg.) p from Λ from Σ^0 ($p=2$ GeV, $\theta=0$ deg.) π^- from Λ from Σ^0 ($p=2$ GeV, $\theta=0$ deg.)

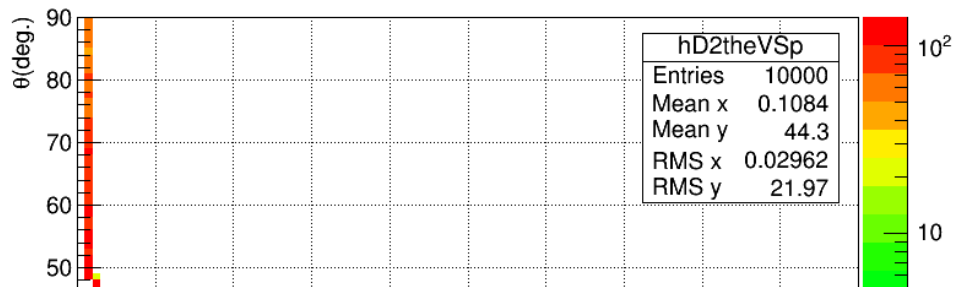
C+C at 3AGeV
 100000 generated events
without kinematic cuts

All particles:	3269875	
Protons	973357 (29.8%)	
Neutrons	974936 (29.8%)	
Σ^+	13035 (0.39%)	2347 (0.07%)
Σ^0		2918 (0.09%)
Σ^-		2277 (0.07%)
Λ		5493 (0.17%)
π^+		269480 (8.2%)
π^0	849431 (25.9%)	312142 (9.5%)
π^-		267809 (8.2%)

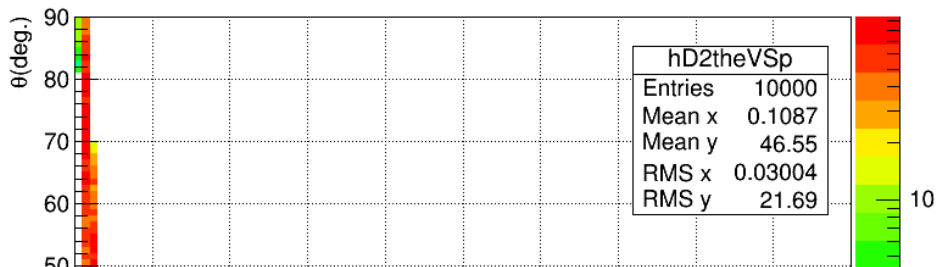
Photon(ECAL Acceptance) $\sim 1\%$;
 $\Lambda \sim 1/10$; Rate estimate $\sim 0.3 \text{ sec}^{-1}$

The UrQMD Model
 (The Ultrarelativistic Quantum Molecular
 Dynamics model)
 v. 3.4 (<http://urqmd.org/documentation/>)

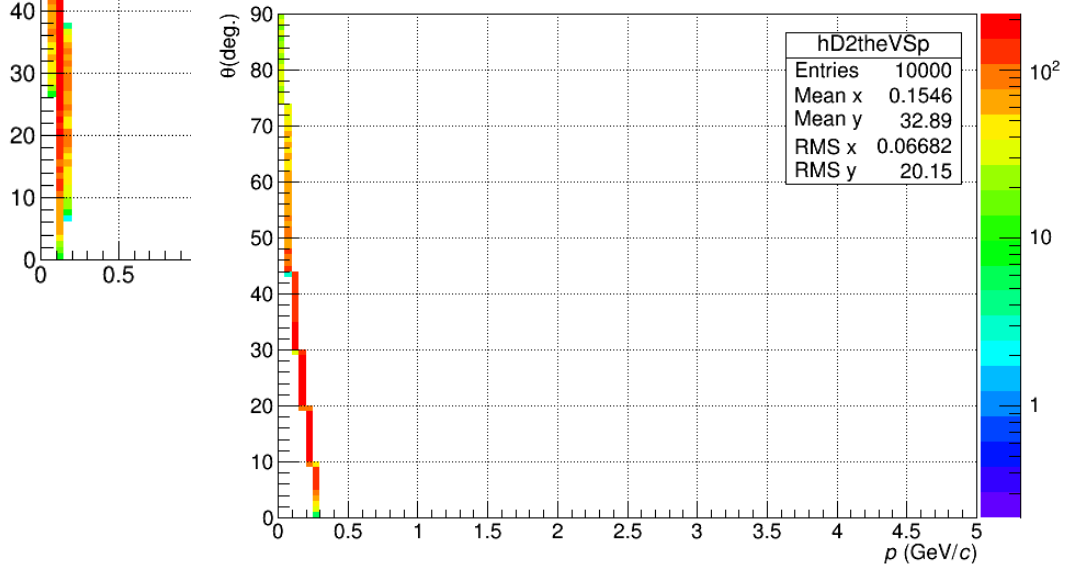
γ from Σ^0 ($p=1$ GeV, $\theta=0$ deg.)



γ from Σ^0 ($p=1$ GeV, $\theta=22$ deg.)



γ from Σ^0 ($p=2$ GeV, $\theta=0$ deg.)



S/B~1/10

Mass resolution estimate (D.Kirin, ITEP)

Generator-UrQMD, Au-Au 4AGeV, 10^4 events

Input1(Vasendina,Zinchenko):Generator:

QGSM, d + 12C, $E_{kin} = 4$ GeV, minbias

Geometry: 6 stations of GEM

Magnetic field: FieldMap -

field_sp41v1_ascii_Extrap.dat ($B = 0.44$)

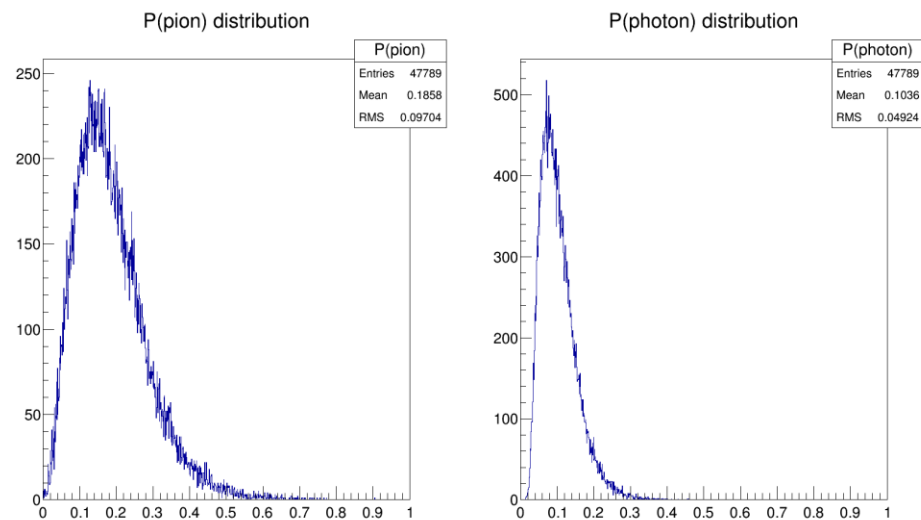
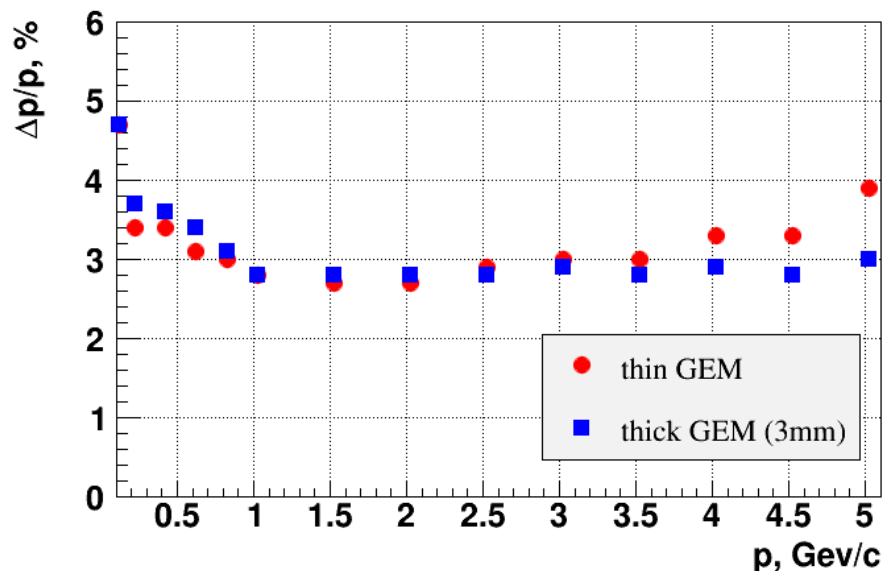
Input2(Tyapkin) ECAL resolution

$$\sqrt{(3\%/ \sqrt{E})^2 + 3\%^2}$$

Input3(Larin, Tarasov):

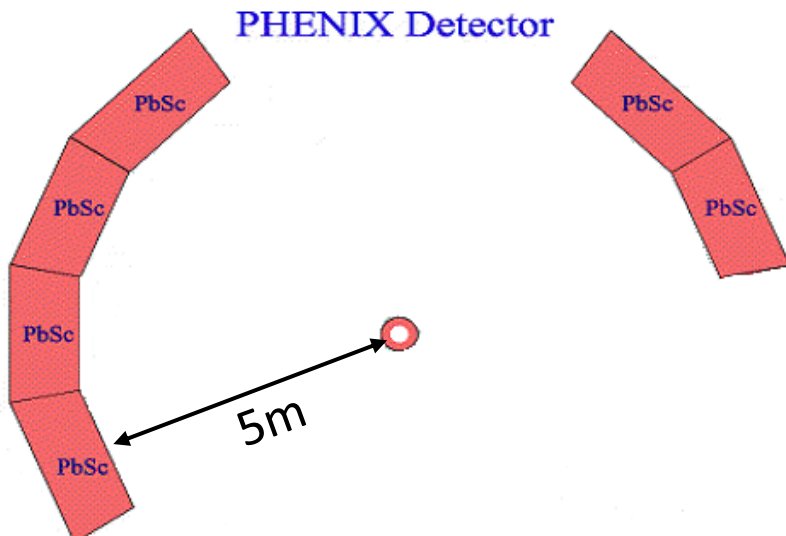
ECAL resolution for $E_\gamma > 100$ MeV

$$5\%/\sqrt{E}$$



		Gauss P(P)	Gauss P(Pi)	Gauss P(P, Pi)	Gauss P(G)			Gauss P(P, PI, G)		
					$dP(g)=5\%/√E$	$dP(g)=3\%/√E$	$dP(g)=\sqrt{((3\%/√E)^2+3\%^2)}$	$dP(g)= 5\%/√E$	$dP(g)= 3\%/√E$	$dP(g)=\sqrt{((3\%/√E)^2+3\%^2)}$
Sigma RMS, MeV	B/ o E(g)	1.65	2.06	2.63	10.85	6.54	6.75	11.17	7.05	7.26
	E(g)>100 MeV	1.76	2.11	2.74	8.68	5.24	5.50	9.13	5.91	6.17

Anti Neutrons in PHENIX



Lead Scintillator:

15552 towers

5 m flight path

$\sigma_{\text{tof}} \sim 500\text{ps}$

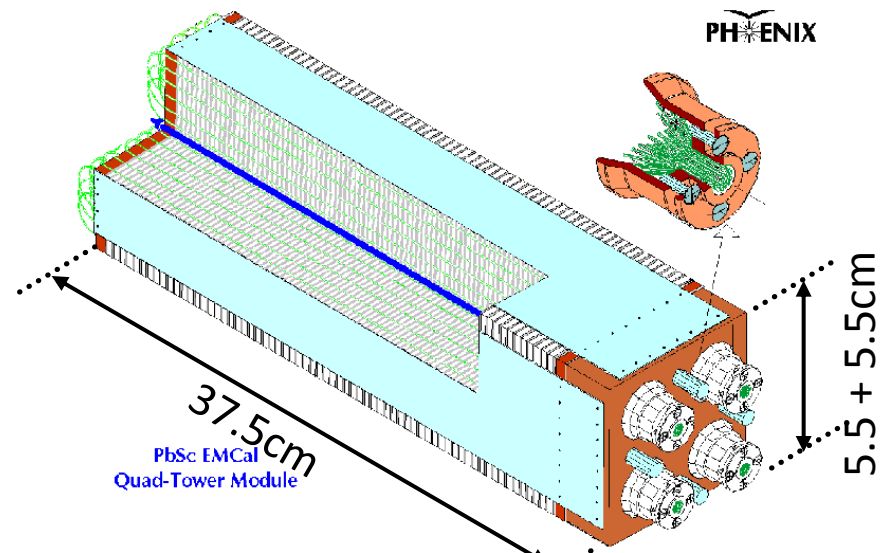
Dynamic timing range translates

to $0.7\text{GeV}/c < p_n < 2.8\text{GeV}/c$

Momentum uncertainty due to depth of annihilation?

The light guides transport the light with $0.67c$, the average β of the Anti Neutrons is 0.7 .

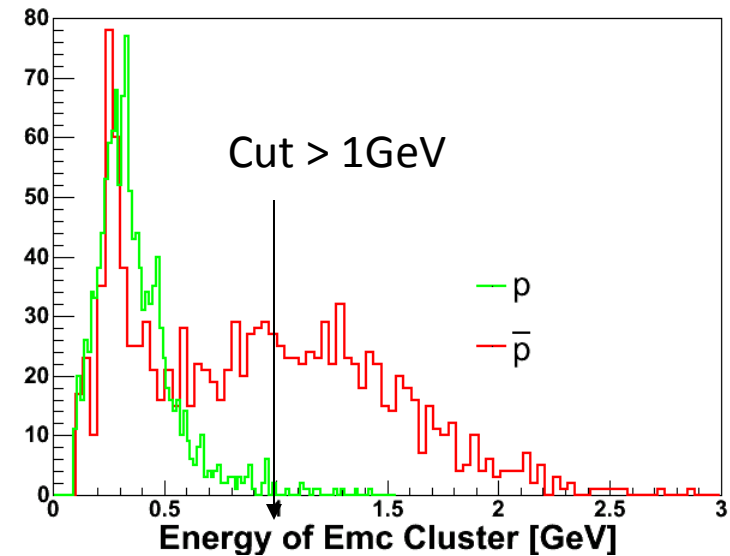
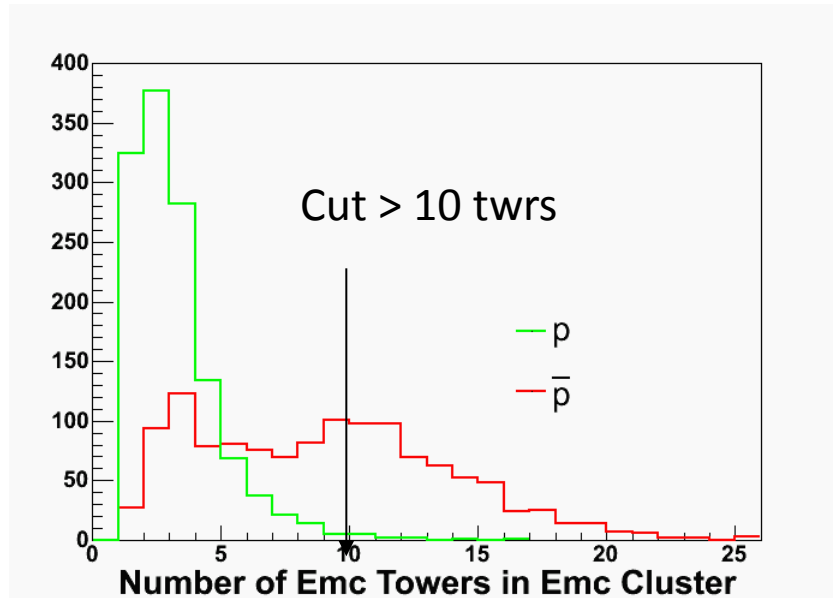
→ Timing (and therefore the momentum of the Anti Neutrons) is not too dependent on annihilation depth



Most problematic is the removal of the Anti Proton contamination, if its track is missed the cluster is indistinguishable from an Anti Neutron

Guidance from (Anti)protons

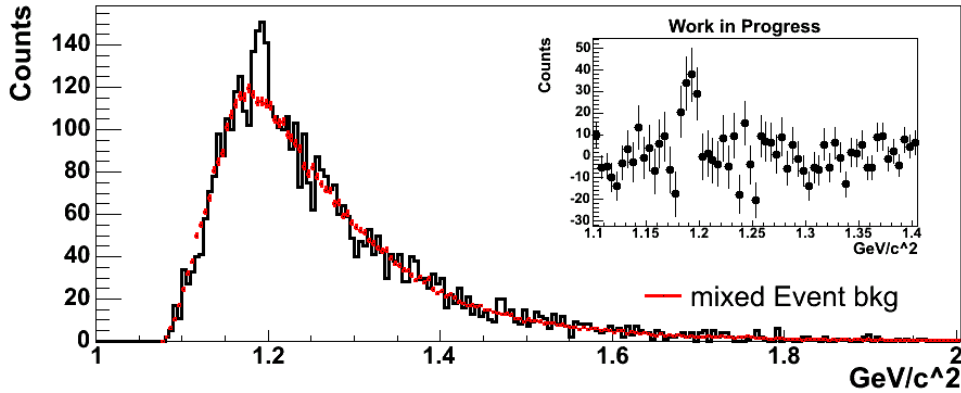
Take identified Protons and Anti Protons and see how EMC-Clusters from annihilation compare to clusters created by charged hadrons



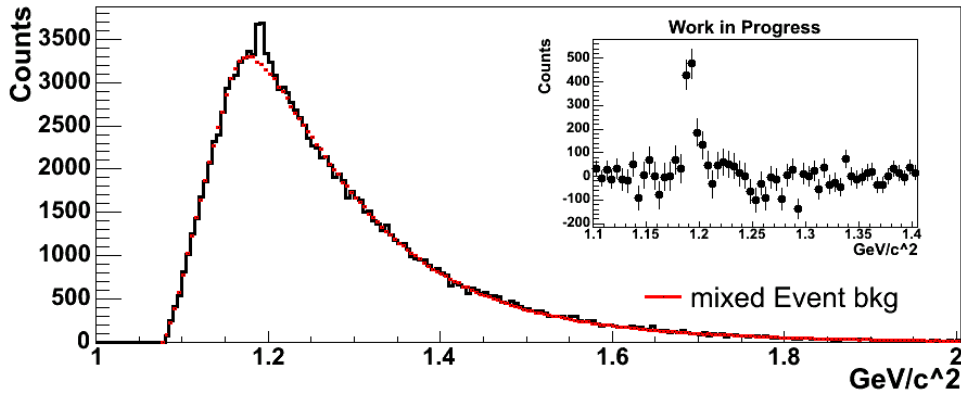
As expected the main difference is the deposited energy and the Number of towers which make up this cluster. Cut at 10 towers and 1 GeV Cluster Energy.

In addition one looks for a bad χ^2 from a fit to a photon shower shape

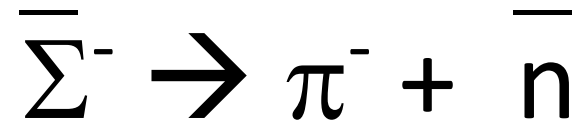
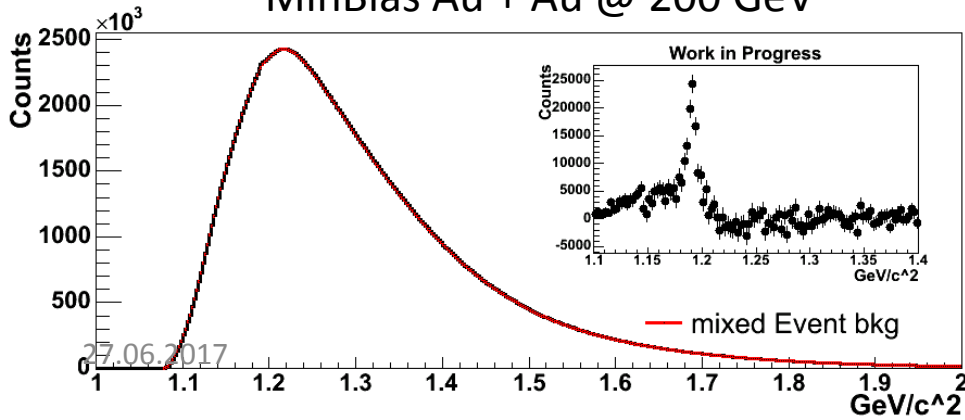
MinBias pp @ 200 GeV



MinBias d +Au @ 200 GeV



MinBias Au + Au @ 200 GeV



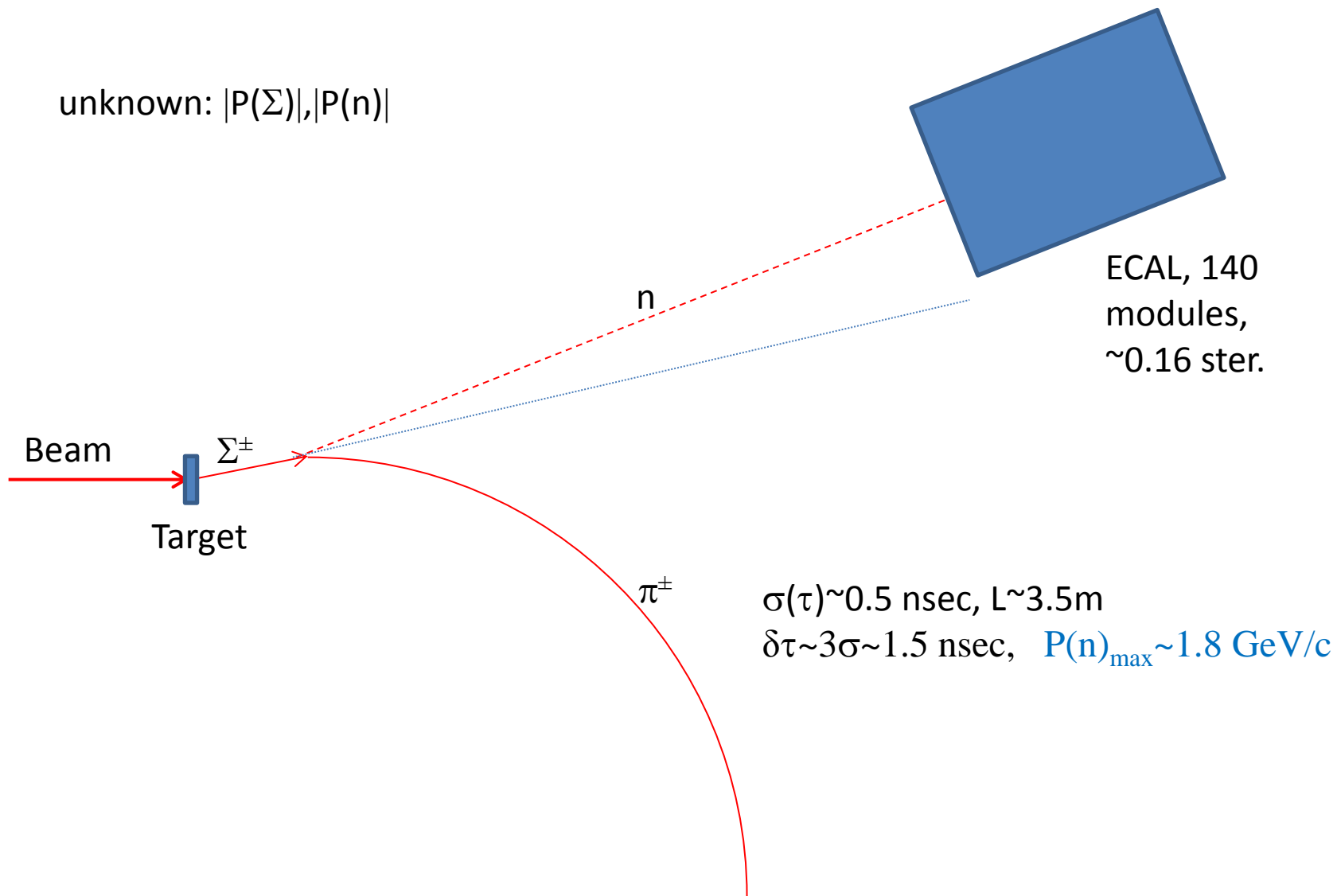
Particle multiplicities in line with branching ratio

$\bar{\Sigma}^- \rightarrow \pi^- + \bar{n}$ (pdg mass: 1189.37 MeV, BR 48.31%)

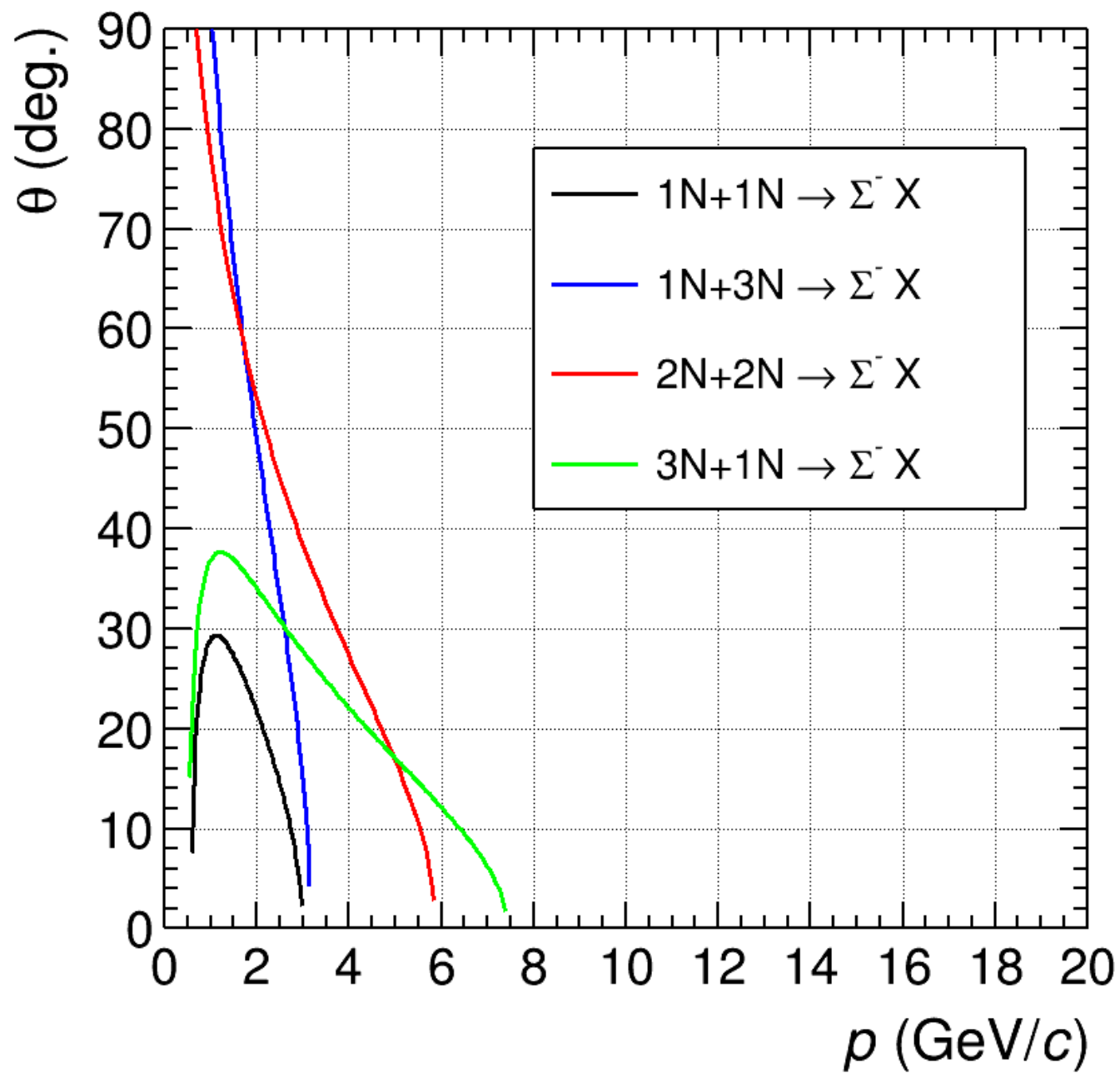
Mass is systematically shifted by $\sim +2$ MeV

Масштаб ширины Σ -10 МэВ

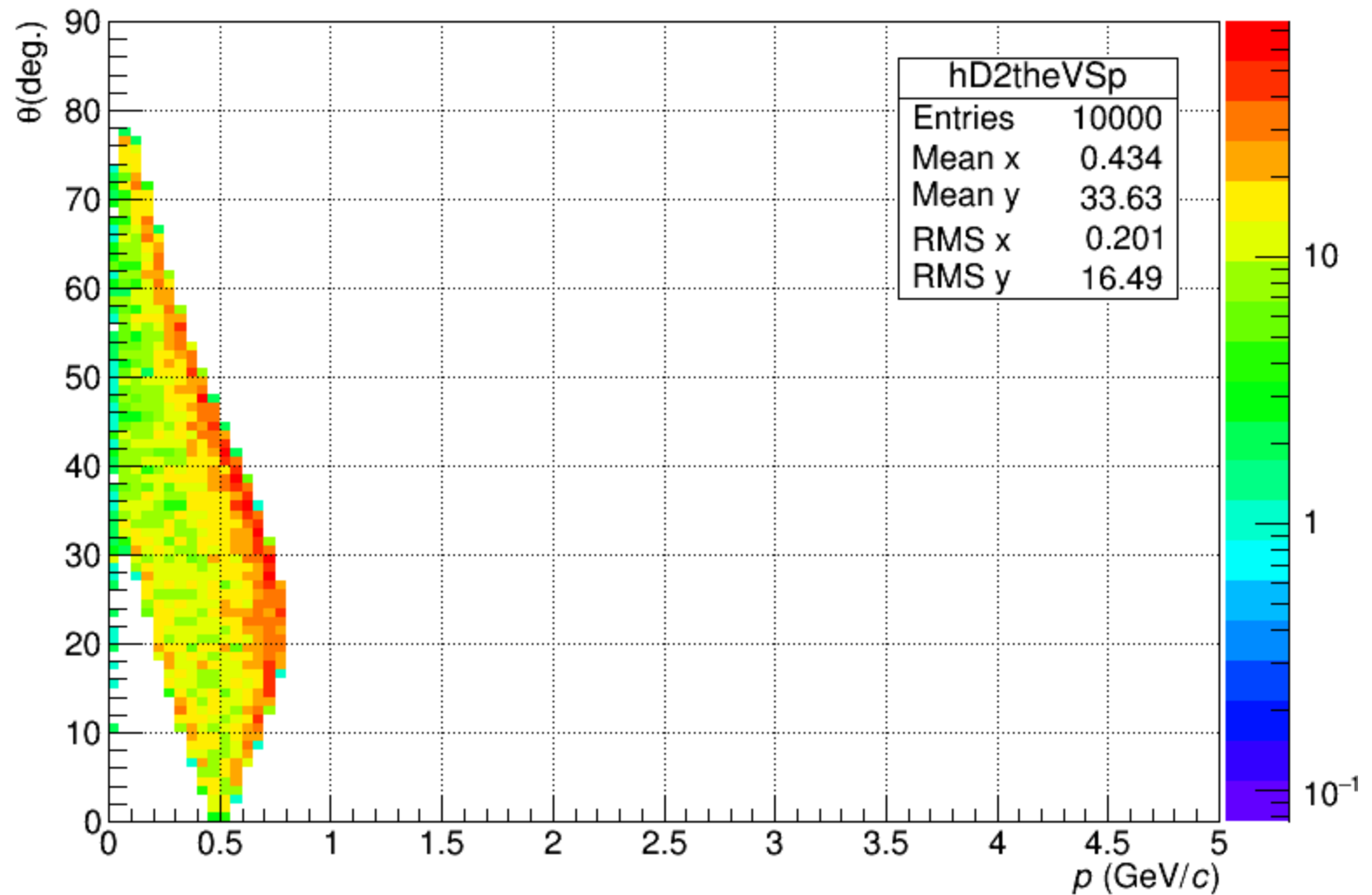
unknown: $|P(\Sigma)|, |P(n)|$



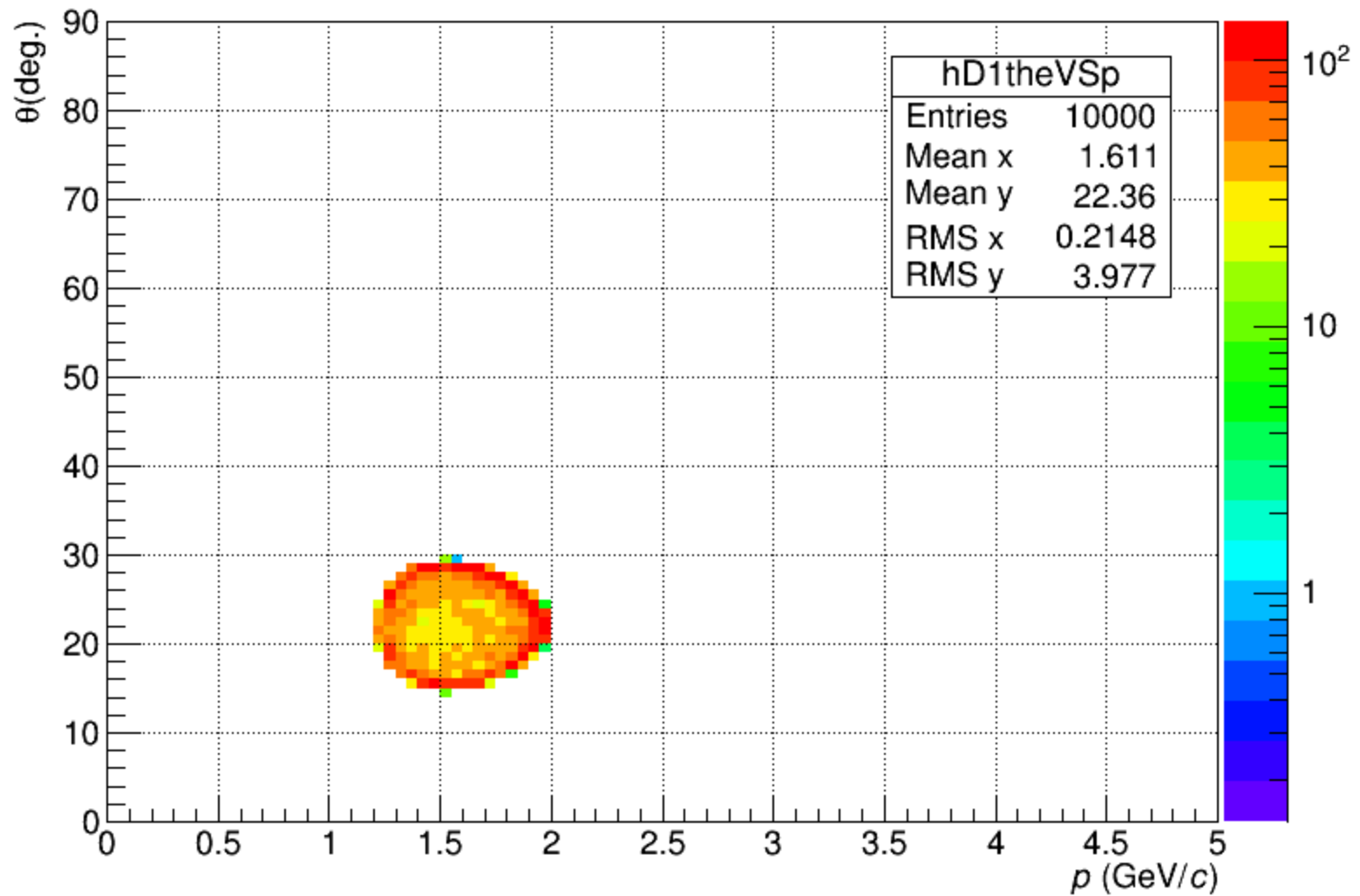
$T_{\text{beam}}/A = 3 \text{ GeV}$



π^- from Σ^- ($p=2$ GeV, $\theta=22$ deg.)



n from Σ^- ($p=2$ GeV, $\theta=22$ deg.)



C+C at 3AGeV
 100000 generated events
 $p_T < 3.0 \text{ GeV}/c$; $|\phi| < 0.12$; $0.17 < \theta < 0.5$

All particles after applying cuts:		59934
Protons	24548 (40.9%)	
Neutrons	24569 (41.0%)	
Σ^+	204 (0.34%)	37 (0.06%)
Σ^0		36 (0.06%)
Σ^-		39 (0.07%)
Λ		92 (0.15%)
π^+	9134 (15.3%)	2928 (4.9%)
π^0		3398 (5.7%)
π^-		2808 (4.7%)

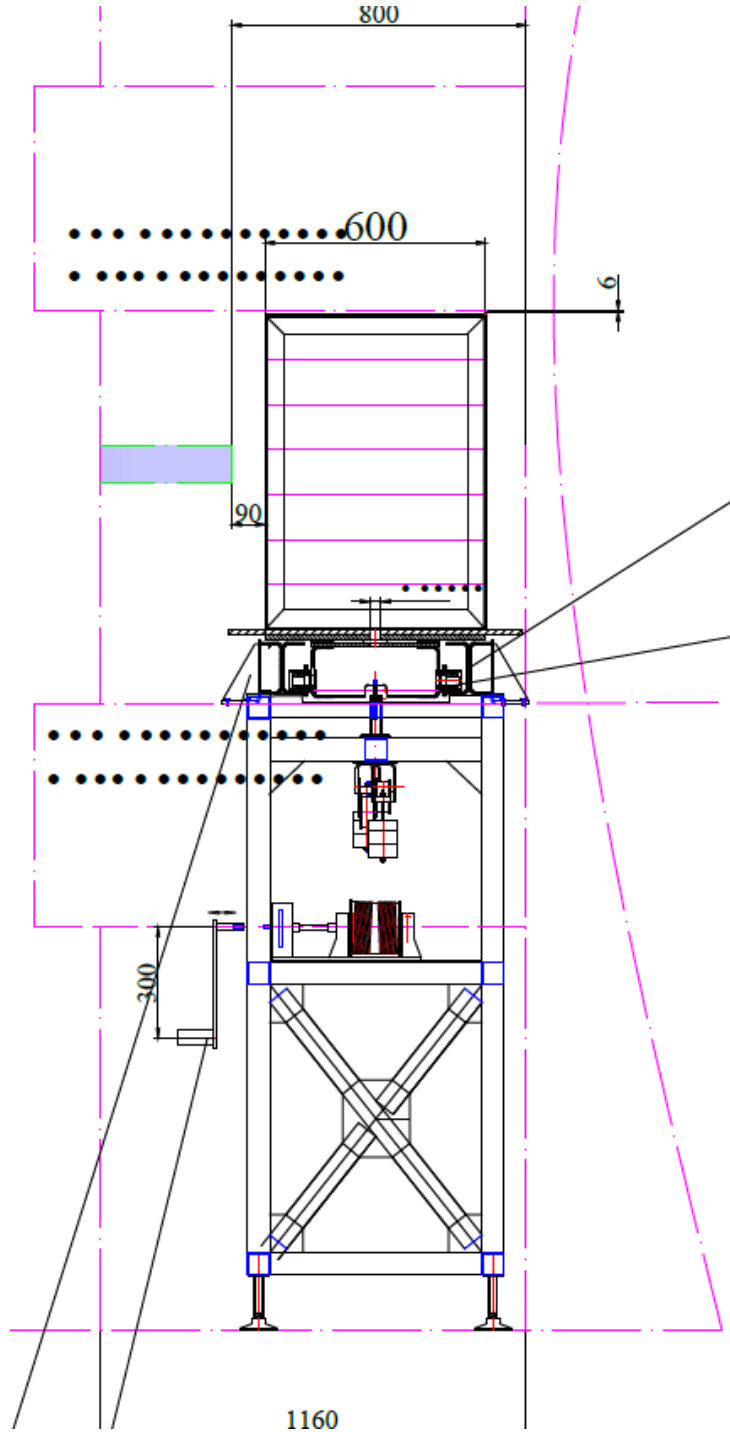
pion $\sim 1/10$; neutron efficiency ~ 0.1 ; Rate estimate $\sim 0.3 \text{ sec}^{-1}$

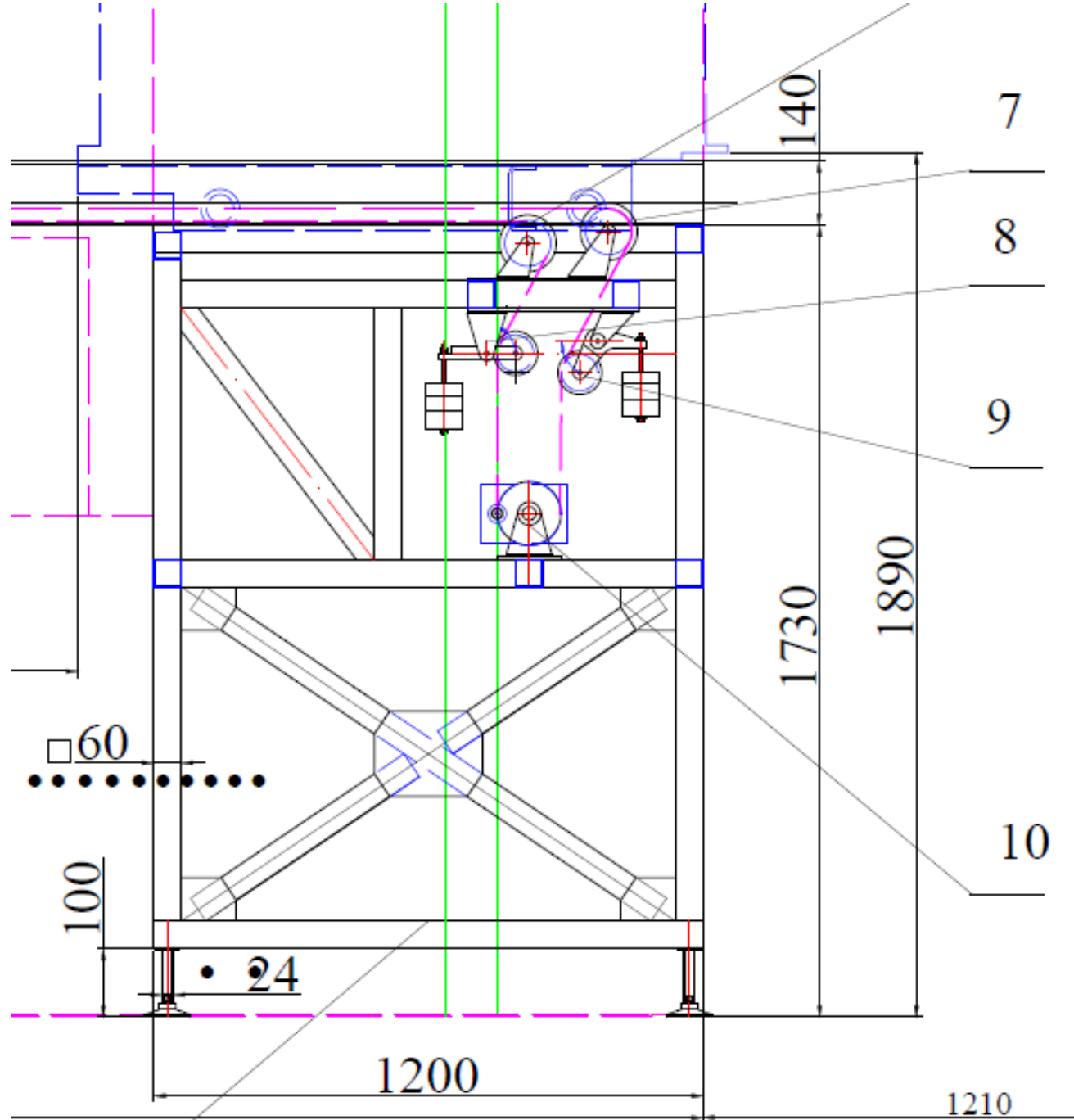
Mass resolution estimate:

“4x2 silicon vertex detectors(strip pitch 100 microns).

$\delta M \sim 10 \text{ MeV} \sim \text{PHENIX}$.

Extra slides





Для холодной плотной барионной материи предложен эффективный триггер, основанный на кумулятивных процессах. Для термализованной теплой кварк-глюонной системы поиски эффективного триггера продолжаются и отбор по величине изотопических эффектов можно предложить в качестве одного из кандидатов. Нужны ли для этого сигма гипероны? Казалось бы это можно сделать, изучая отношения сечений других частиц, например

$$\frac{\pi^+(u\bar{d})}{\pi^-(d\bar{u})},$$
$$\frac{K^+(u\bar{s})}{K^-(\bar{u}s)}$$

Однако, эти пары частиц, кроме интересующего нас отношения u/d , содержат отношения *других* кварков(антикварков), что затрудняет интерпретацию наблюдаемых результатов, как чисто электромагнитный эффект.

n/p

Отношение сечений нейтронов к протонам почти безупречно с точки зрения физики, но **методика** идентификации протонов и нейтронов совершенно различна, что вносит в измеряемые отношения трудноустраняемые систематические ошибки.

${}^3\text{He}/t$

Отношение сечений рождения ядерных фрагментов «завязано» на модель слияния и, следовательно, на **корреляционные функции** нуклонов и **пространственно-временную структуру** взаимодействия.

В отношении сечений сигма гиперонов изотопические эффекты **квадратично усилены и практически не маскируются какими-либо другими физическими эффектами** (разница в кинематике рождения за счет разности масс $\delta M \sim 8 \text{ МэВ}$ мала по сравнению с характерными энергетическими параметрами $T \sim M_{\pi}$, в принципе, может быть оценена; в той или иной мере это надо учитывать для любых пар частиц)

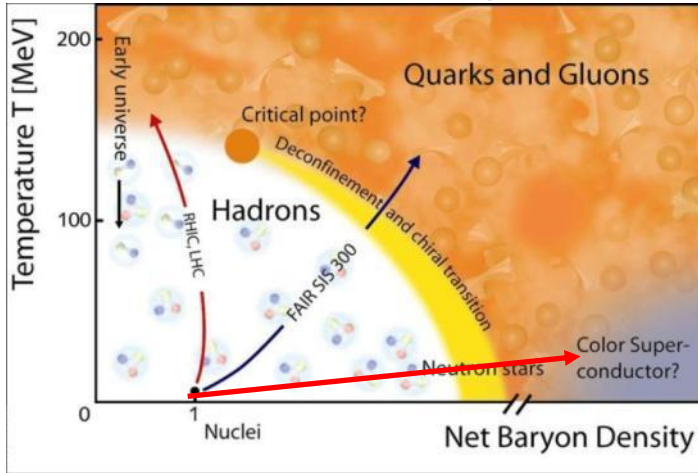
$$\Sigma^-(sdd)/\Sigma^+(suu)$$

Методически при замене полярности магнитного поля условия для идентификации гиперонов противоположного знака заряда отличаются, главным образом, из-за разного времени жизни - τ с для положительно заряженного гиперона 2.4см, а для отрицательного – 4.4см. Более проблемной является идентификация Σ^+ , но для положительного гиперона достоверность результатов может быть повышена сравнением мод распада $\Sigma^+ \rightarrow p\pi^0$ и $\Sigma^+ \rightarrow n\pi^+$

$$\Sigma^- \rightarrow n\pi^- / \Sigma^+ \rightarrow n\pi^+$$

Если под изотопическим эффектом понимать зависимость сечений от **изоспина** (а не от его проекции, что обычно делается и имеется в виду), то здесь у отношения Σ^0/Λ вообще не видно конкурентов. Однако, в отличие от зависимости сечений от знака заряда, которая сравнительно очевидно соотносится с влиянием заряда сталкивающихся ядер, роль изоспина в ядерной материи не столь прозрачна.

Phase diagram*



*http://www.gsi.de/forschung/fair_experiments/CBM/

Kinematical limits for different subprocesses:

1N+1N(black line)

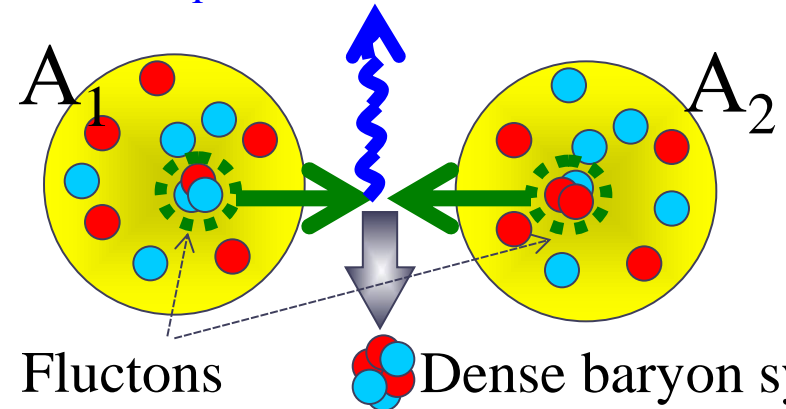
1N+Flucton(2N,3N,4N)&Flucton+1N
(blue lines)

Flucton+Flucton(red lines)

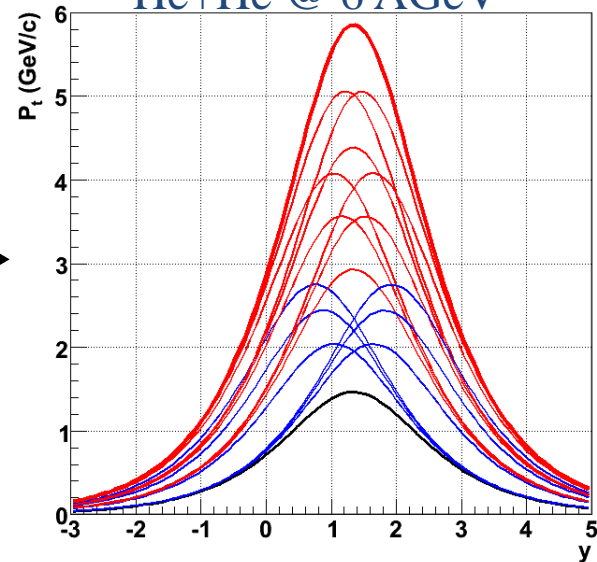


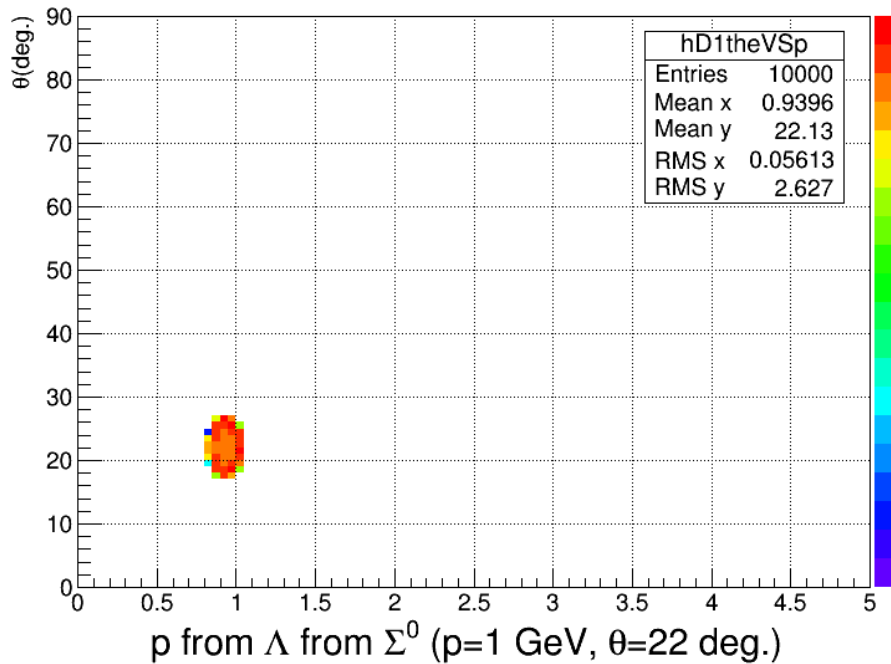
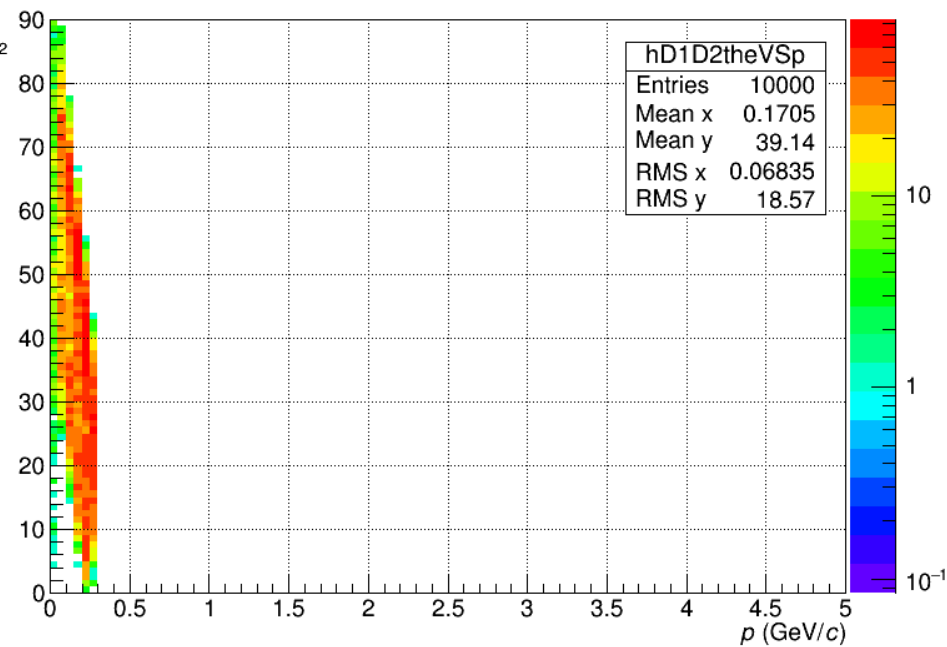
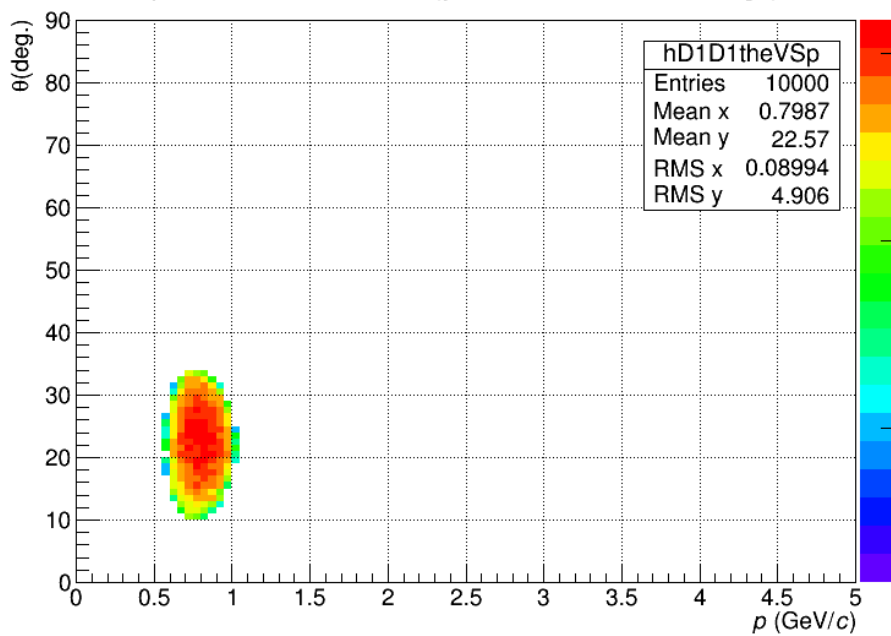
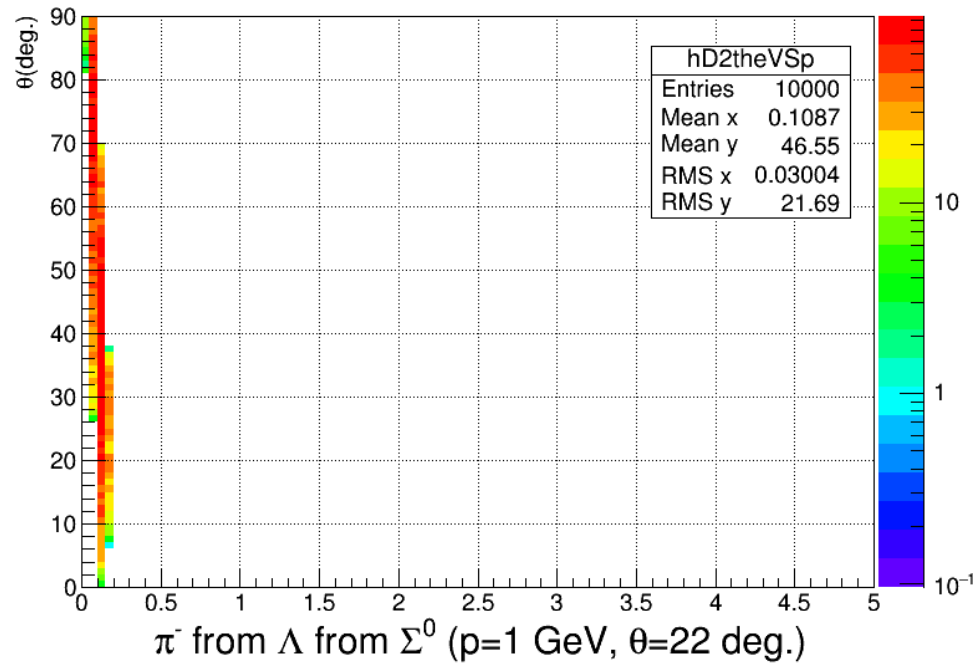
Scheme of process

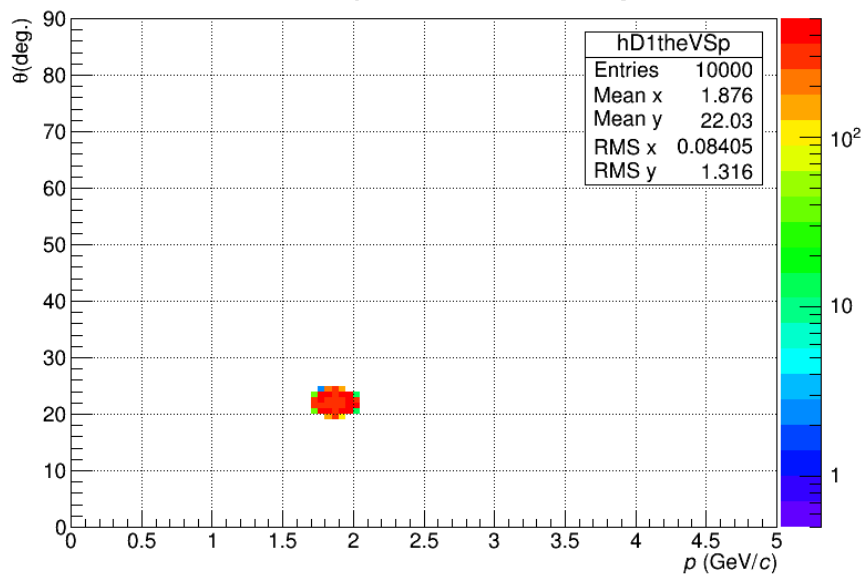
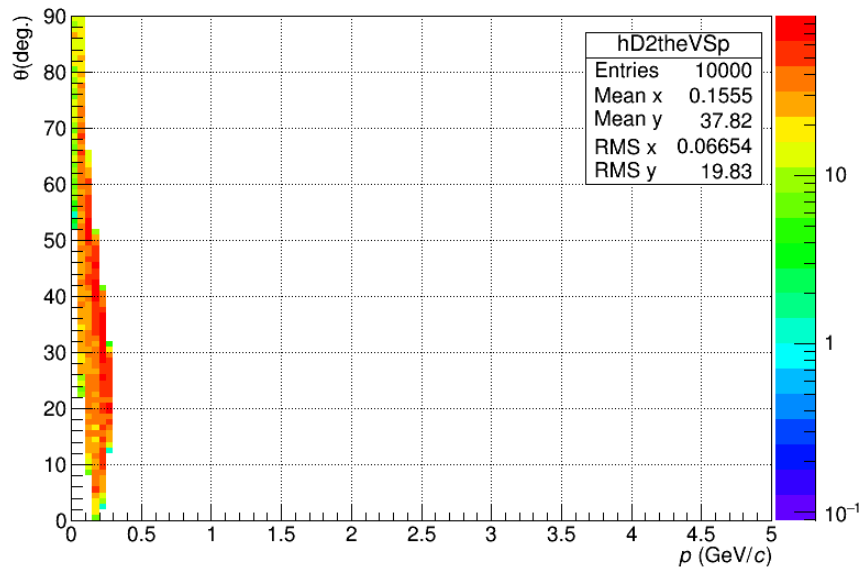
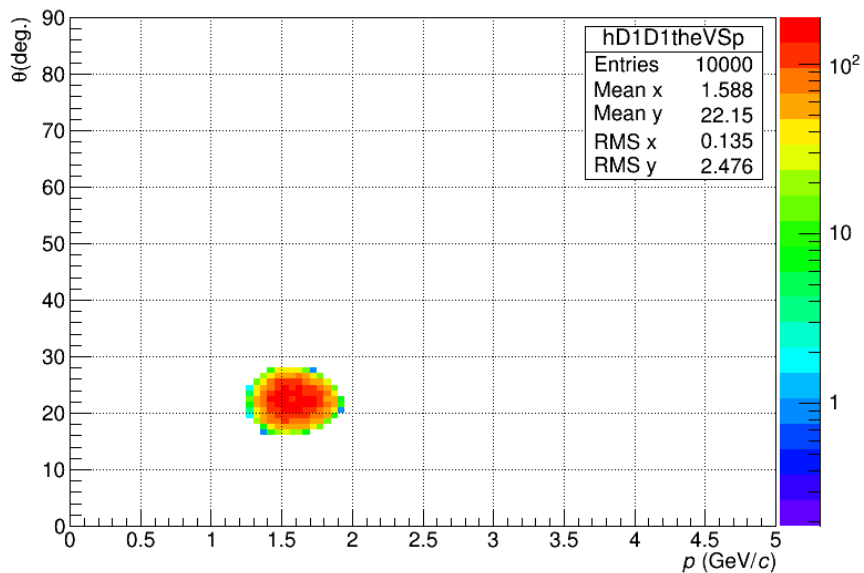
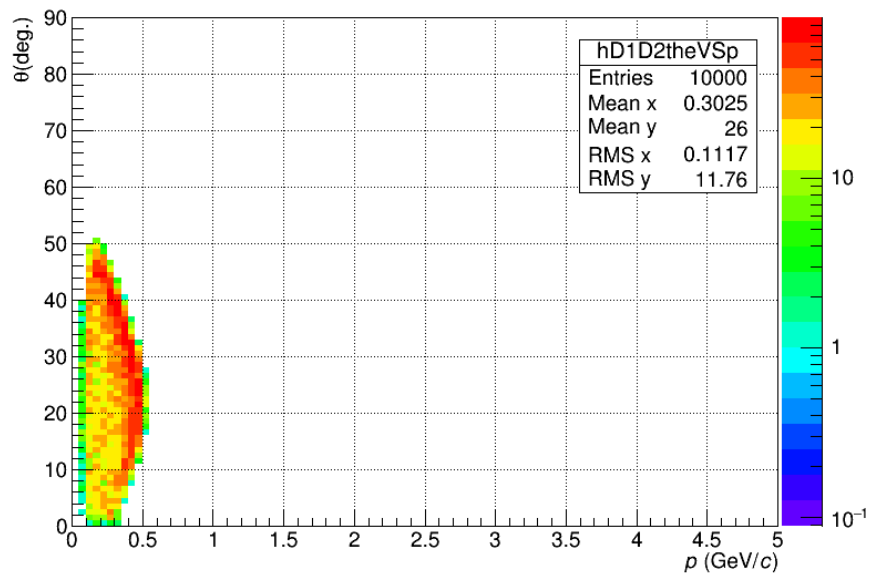
High p_T trigger $\gamma, \gamma(\pi^0), \dots$



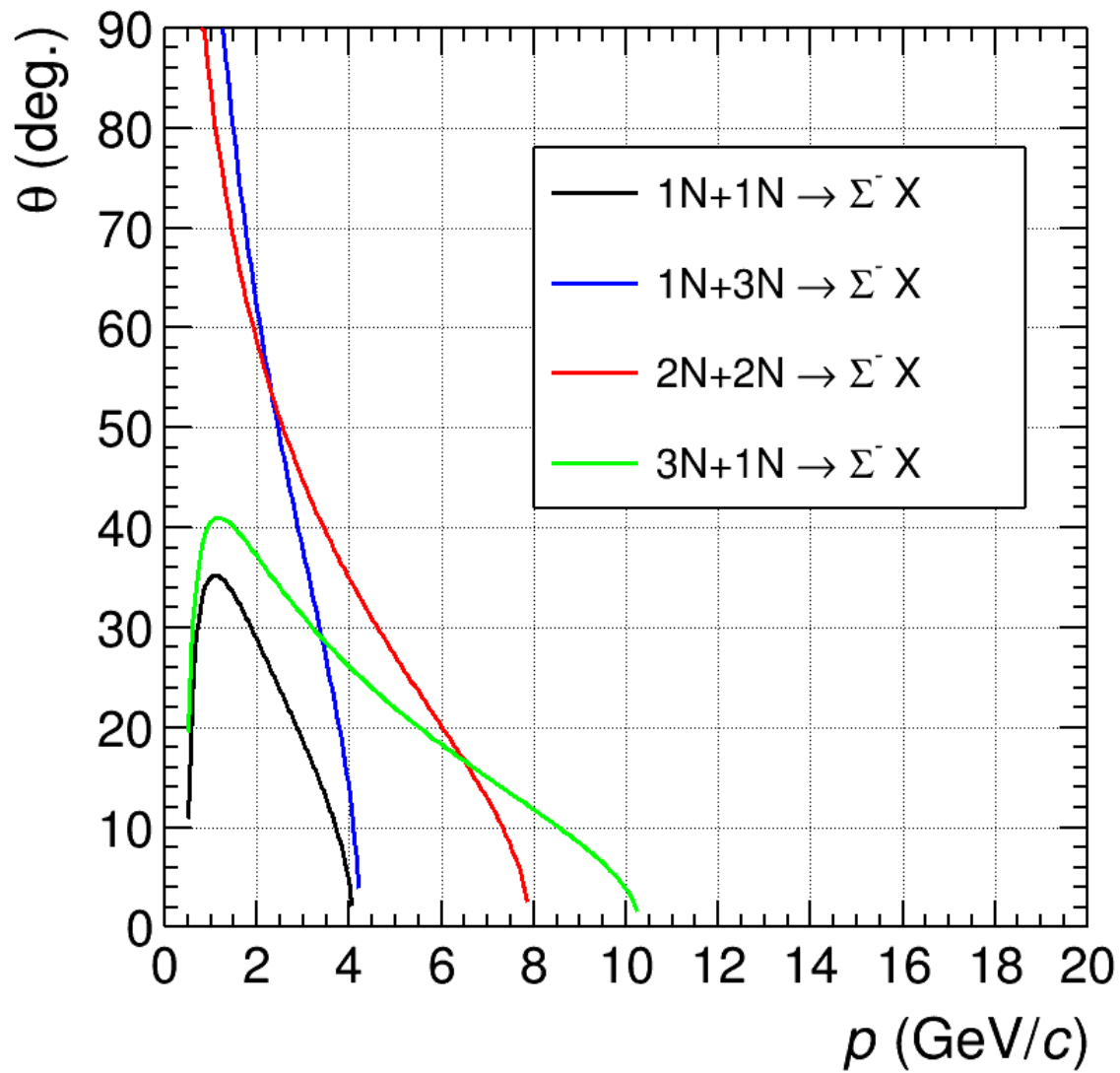
He+He @ 6 AGeV



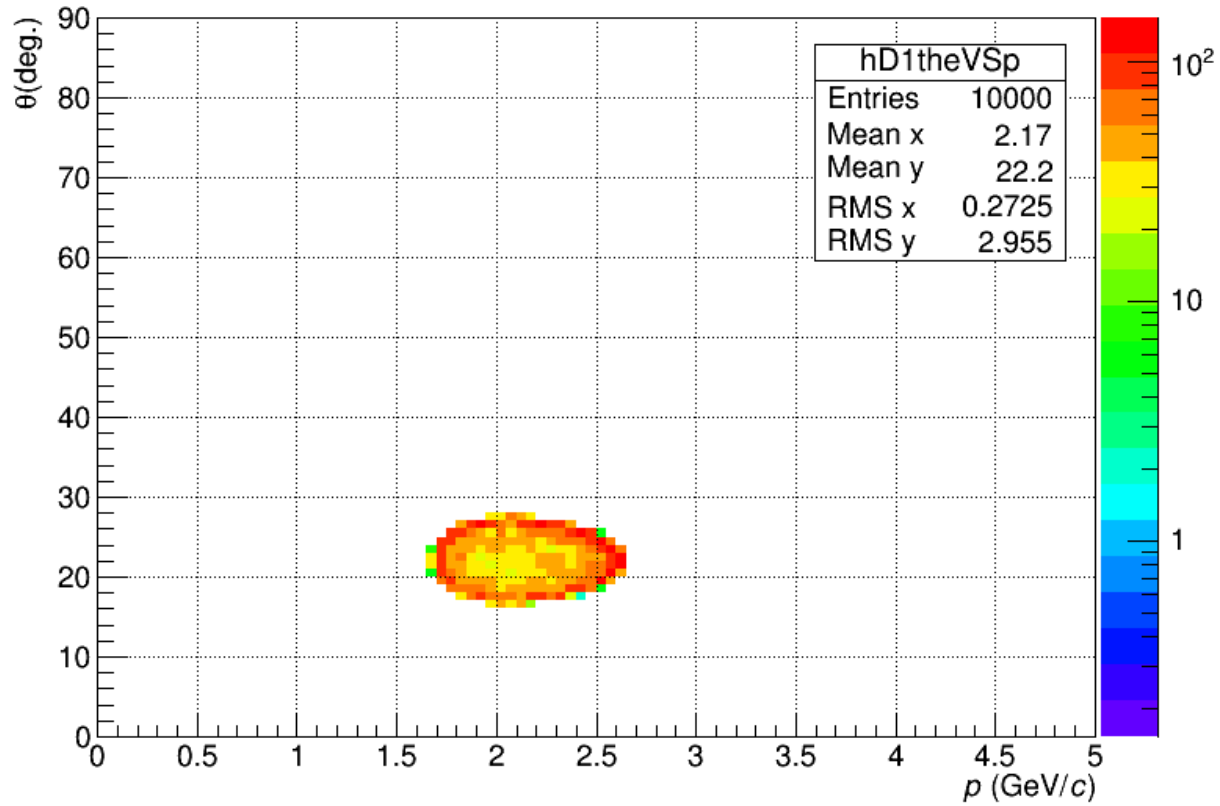
Λ from Σ^0 ($p=1$ GeV, $\theta=22$ deg.) γ from Σ^0 ($p=1$ GeV, $\theta=22$ deg.)

Λ from Σ^0 ($p=2$ GeV, $\theta=22$ deg.) γ from Σ^0 ($p=2$ GeV, $\theta=22$ deg.) p from Λ from Σ^0 ($p=2$ GeV, $\theta=22$ deg.) π^- from Λ from Σ^0 ($p=2$ GeV, $\theta=22$ deg.)

$T_{\text{beam}}/A = 4 \text{ GeV}$



n from Σ^- ($p=2.7$ GeV, $\theta=22$ deg.)



π^- from Σ^- ($p=2.7$ GeV, $\theta=22$ deg.)

